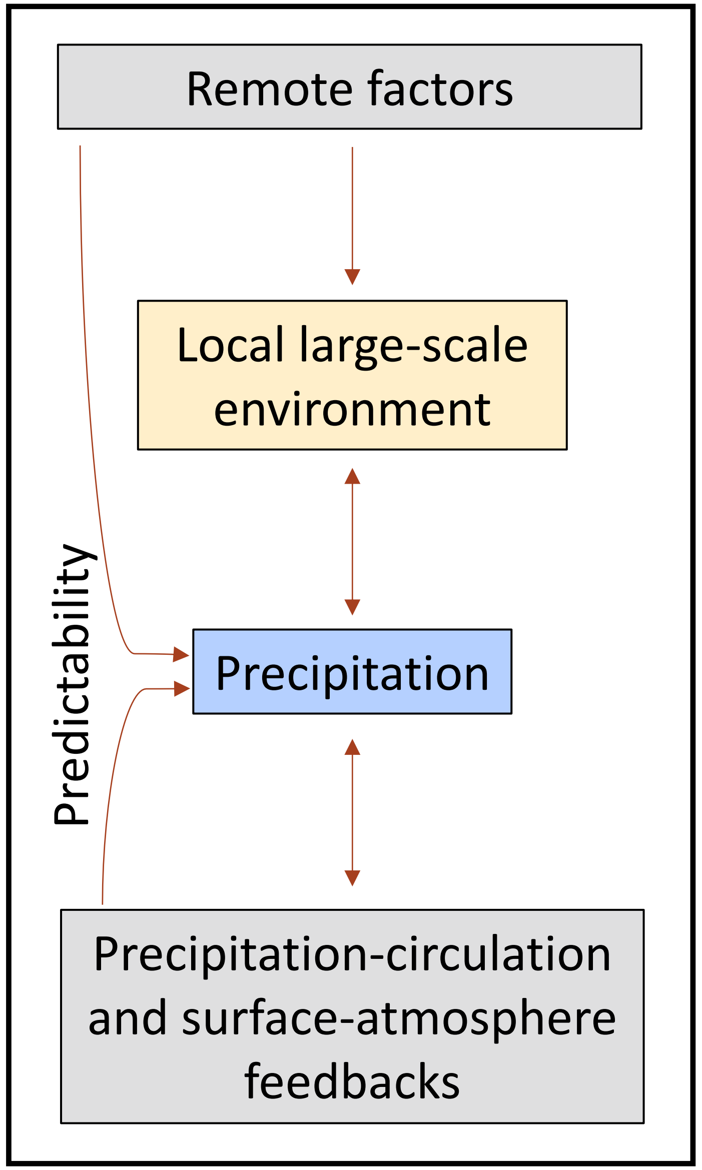
Teleconnection and local feedbacks are important sources of precipitation predictability and biases

- A foundational concept used in developing model parameterizations is the existent **relationships between the parameterized process**es (e.g., convection) **and the (resolved) local large-scale environment** (e.g., wind shear, CAPE)
- Single column model, initialized forecast, and nudging have been useful frameworks for **constraining the large-scale environment** for model development and evaluation
- However poor precipitation prediction skill is often a result of poor simulation or prediction of: (1) local large-scale environment related to **remote tele-connected processes** and (2) **local feedback** processes that amplify the errors
- These two factors also provide **sources of precipitation predictability** so their **poor representations in models also limit precipitation prediction skill**
- **Diagnostics and metrics of precipitation** should include:
  - Relationships between local large-scale environment and remote factors
  - Metrics of surface-atmosphere and precipitation-circulation feedbacks

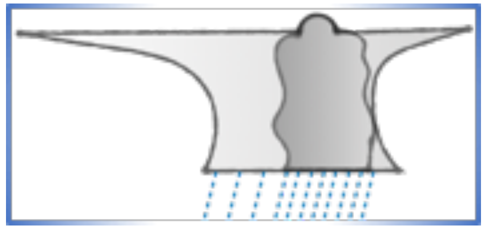


Soil moisture-precipitation feedback as an amplifier of precipitation error and limits of precipitation predictability

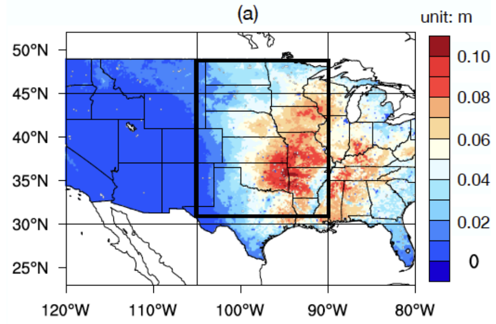
Models that simulate fewer / weaker MCSs in early warm season may have larger biases in simulating summer precipitation by breaking the soil moisture-precipitation feedback

Inferences from numerical tracer experiments that tag the transit of water associated with MCS and non-MCS rainfall

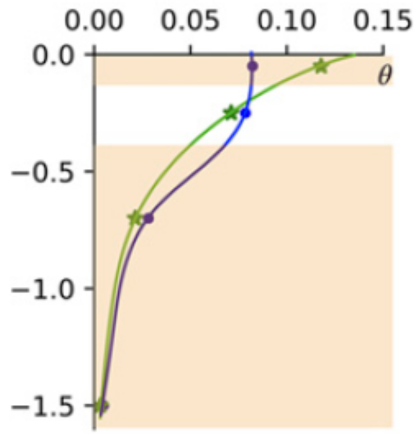
MCS produces more intense rain with larger rain area



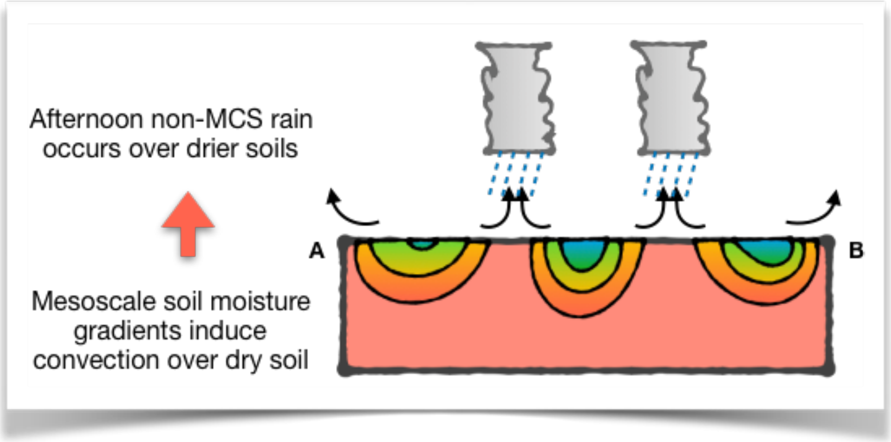
MCS rain produces larger soil moisture anomalies with stronger gradients



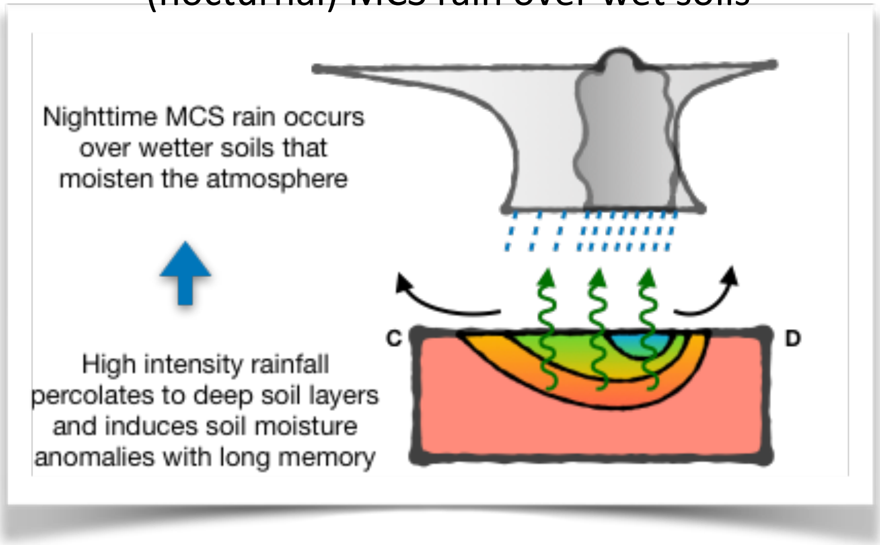
MCS rain percolates deeper in the soil layers with longer memory



Earlier season MCS rain favors summer (afternoon) non-MCS rain over dry soils



Earlier season MCS rain favors summer (nocturnal) MCS rain over wet soils



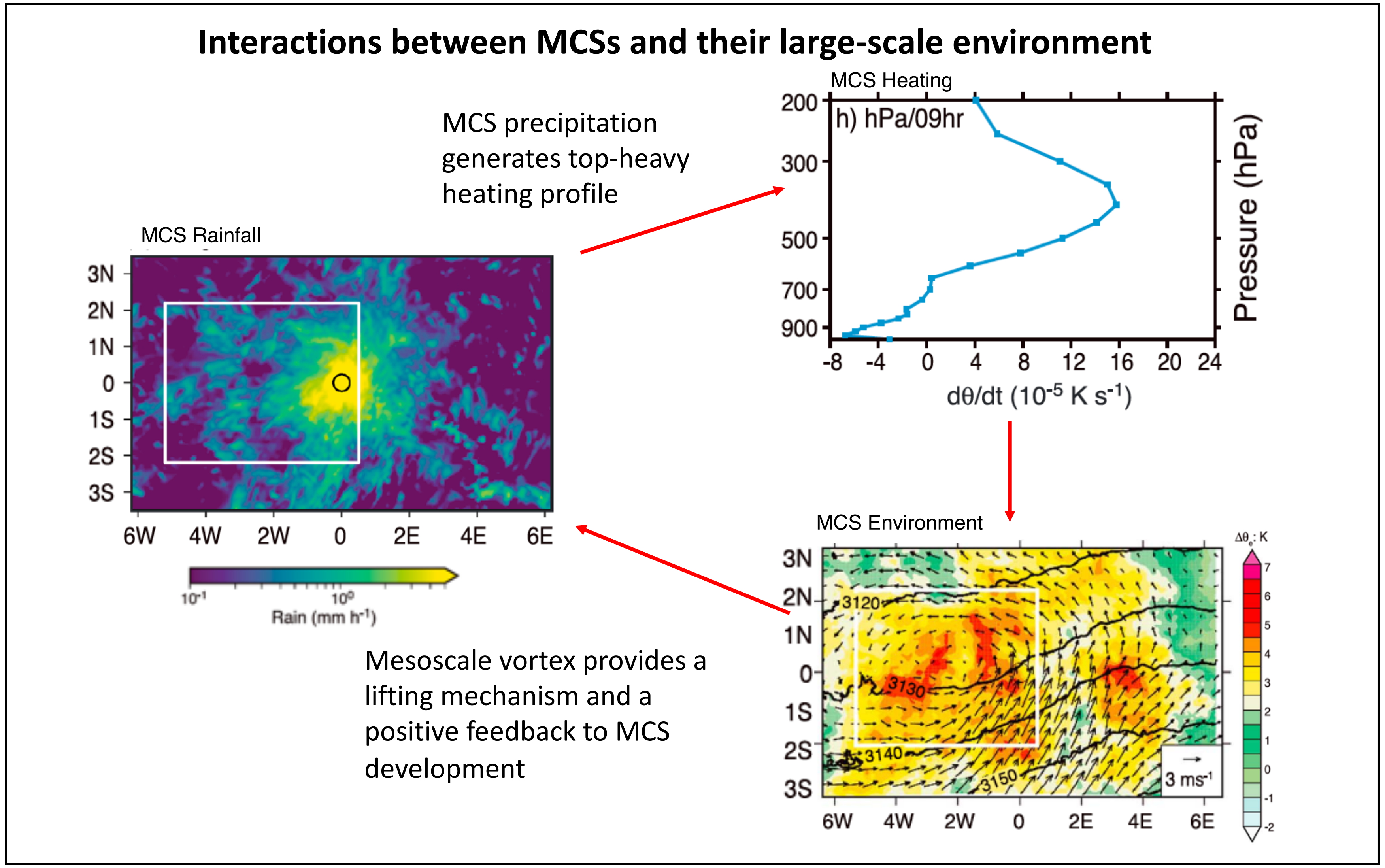
Hu, H., L.R. Leung, and Z. Feng. 2020. "Observed Warm-Season Characteristics of MCS and non-MCS Rainfall and Their Recent Changes in the Central United States." *Geophys. Res. Lett.*, 47, doi:10.1029/2019GL086783.

Hu, H., L.R. Leung, and Z. Feng. 2020. "Understanding the Distinct Impacts of MCS and Non-MCS Rainfall on the Surface Water Balance in the Central US Using a Numerical Water-Tagging Technique." *J. Hydrometeor.*, 21, 2343-2357, doi:10.1175/JHM-D-20-0081.1.

Hu, H., L.R. Leung, and Z. Feng. 2020. "Earlier-Season Mesoscale Convective Systems Dominate Soil Moisture-Precipitation Feedback for Summer Rainfall in Central US." Submitted.

Precipitation-circulation feedback as an amplifier of precipitation error and limits of precipitation predictability

Long-lived MCSs produce a midlevel circulation anomaly in response to the latent heating that strengthens the environmental trough and maintains the MCSs – latent heating profile is sensitive to cloud microphysics

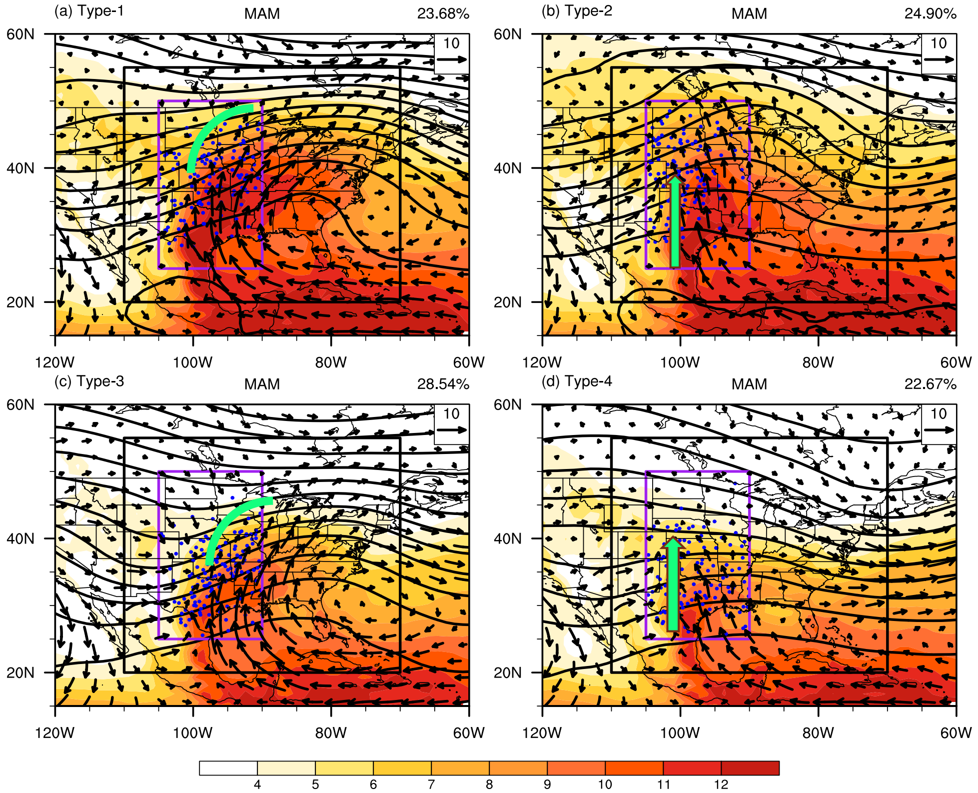


Yang, Q., R. Houze, Jr., L.R. Leung, and Z. Feng. 2017. "Environments of Long-lived Mesoscale Convective Systems over the Central United States in Convection Permitting Climate Simulations." *J. Geophys. Res.*, 122, doi: 10.1002/2017JD027033.

Teleconnection between MCS large-scale environment and remote circulation features contributes to MCS biases

MCS large-scale environments during spring determined using self-organizing map analysis

Frontal system | Great Plains LLJ



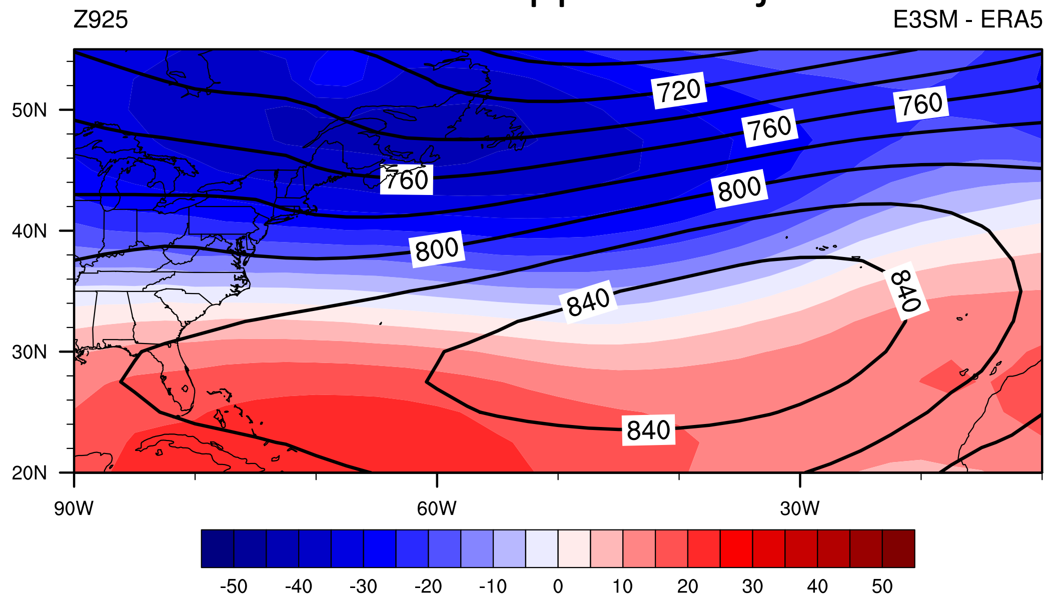
MCS large-scale environments simulated with much lower frequency compared to observations

Number of occurrences per season of each type of environment

Data	Type-1	Type-2	Type-3	Type-4	Total
NARR	55.2	31.9	40.0	57.5	193.6
E3SM HR	5.2	3.0	9.2	15.6	34.0
E3SM HR (U)	15.5	7.1	22.4	27.1	72.1
E3SM HR (V)	8.6	4.7	18.0	28.9	60.2
E3SM HR (Q)	4.4	4.7	6.2	12.9	28.2

Accounting for biases in: U, V, Q

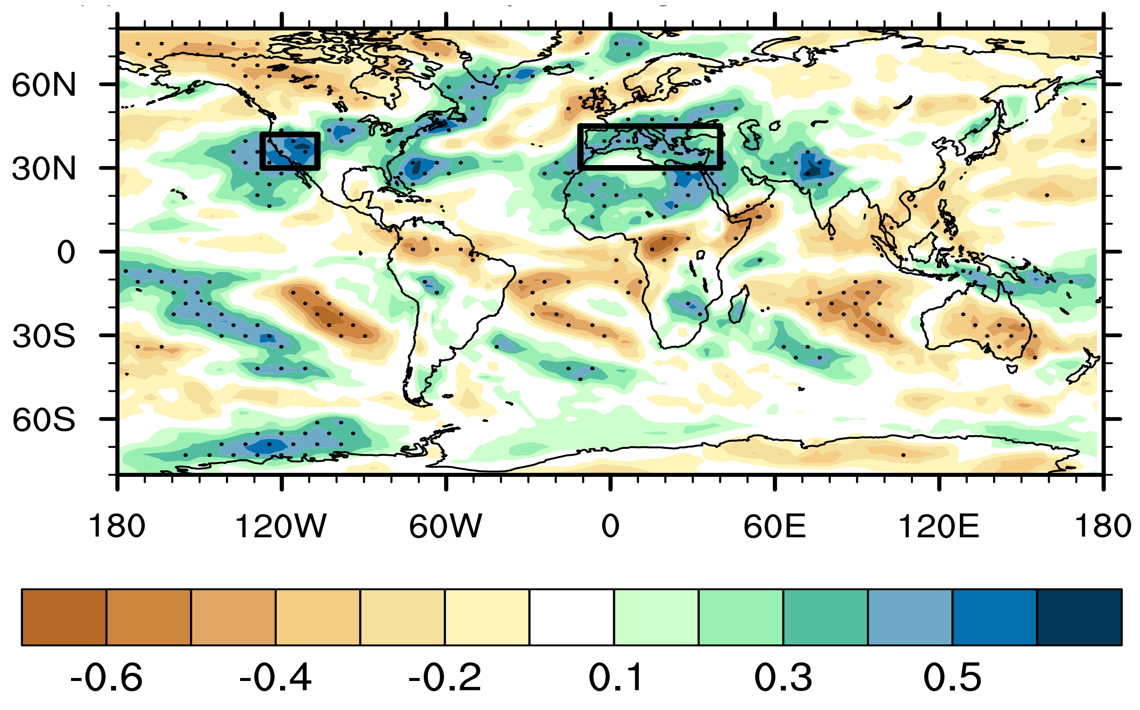
Equatorward displacement of North Atlantic Subtropical High in model leads to southward displacement of the GPLLJ and upper-level jet



Feng, Z., F. Song, K. Sakaguchi, and L.R. Leung. 2020. "Evaluation of Mesoscale Convective Systems in Climate Simulations: Methodological Development and Results from MPAS-CAM over the U.S." *J. Clim.*, doi:10.1175/JCLI-D-20-0136.1.

Double ITCZ bias increases future winter wetting trends in US Southwest and contributes to uncertainty in future projections

Significant correlation between present-day double-ITCZ and future precipitation changes in US Southwest and Mediterranean Basin



Dong, L., L.R. Leung, J. Lu, and F. Song. 2020. "Double-ITCZ as an Emergent Constraint for Future Precipitation Over Mediterranean Climate Regions in the North Hemisphere." *Geophys. Res. Lett.*, submitted

Models with larger double-ITCZ increase precipitation in central Pacific more, which strengthens the westerly jet and Aleutian low, increasing winter precipitation in southwestern US